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Editorial

Intelligent Systems Supporting the Use of Energy Devices and Other Complex Technical Objects: Modeling, Testing, and Analysis of Their Reliability in the Operating Process

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1. Introduction

Among the technological developments for complex technical objects such as civil aircraft, energy systems, medical devices, etc., intelligent assistance systems hold a special position. Currently, intelligent consulting systems are used to supervise the effective use of objects and to organize operational, technical, technological, and other processes. Intelligent systems are particularly useful in the diagnosis of technical objects and qualitative assessment of their reliability. Intelligent systems are also of particular benefit when many variables are covered in the analyzed process, and complex factors need to be considered that affect the conditions of the use of technical objects. Other functions in which intelligent support systems prove useful include the processes of testing the reliability conditions of technical devices, selecting tools and means in the production process, and assessing the selection of conditions and parameters in the process of use. Intelligent systems can also be used to restore the functionality of complex technical objects such as energy, medical, security, and other systems. This is an important part of their application.

The optimal and effective renovation of technical objects is possible only with the use of intelligent systems that support human activity (the user of the object). An optimal system for the service and operation of technical objects is one in which the object is renewed exactly when it is required. Such an approach is ensured by an intelligent object diagnosis system, which is built on an artificial neural network. The neural network reliably and consistently recognizes the states of the object for which remedial actions need to be taken and repair procedures to be performed. Organizing the process of the exploitation of objects using artificial intelligence provides significant advantages. Notably, no losses (e.g., financial) occur related to the ineffective use of the facility, when a failure may occur during the facility's operation, meaning that the facility is not fit or not fully operational. In addition, an intelligent system eliminates the costs associated with the renewal of unnecessary elements, i.e., elements of the facility that do not require it because they are fit. The intelligent system designed for servicing the object ensures the high efficiency of the provided service and ensures the renewal of those internal–structural elements that require the service because they are in a state of incomplete fitness {1} or unfitness {0}.

Currently, cognitive aspects in the use of intelligent systems supporting the use and operation of technical objects are particularly important, especially in the fields of modeling the operating processes of the tested technical objects, as well as the research, evaluation, and analysis of the reliability of the operating processes of objects using intelligent systems.

The structure of this Special Issue consists of six thematic sections. In Section one, the estimation of information quality (IQ) in information and communication technologies (ICT) systems were addressed. Several recent publications were analyzed in this context, as well as the ISO standards concerning quality and information quality. Due to the limitations of the known methods of IQ estimation, the authors presented their own proprietary concept based on multidimensional and multilayer modeling using methods of estimating uncertainty.

The six articles that constitute this Special Issue's six-theme collection on "Intelligent Systems Supporting the Use of Energy Devices and Other Complex Technical Objects: Modeling, Testing, and Analysis of their Reliability in the Operating Process" are briefly summarized in this editorial. Each article outlines what is novel in the contribution.

2. Determining Information Quality in ICT Systems

In the information and communication technology (ICT) systems discussed in [1], the authors addressed the estimation of information quality (IQ). Numerous recent publications, as well as ISO criteria for information quality, were examined. The authors introduced their own proprietary approach based on multidimensional and multilayered modeling employing methods of uncertainty estimation consequent to the shortcomings of the existing IQ estimation techniques. The modeling suggested in this contribution makes use of 16 quality dimensions that have been documented in the literature. The features of these dimensions were added as a second layer, and the states of information were added as further modifications to the model. An example of calculation was also presented in which the authors included model-dependent aspects in the mathematical proof method used for uncertainty estimation, followed by a simulation based on the provided example. The assumed relationships between the input and output values were investigated through this simulation.

In another contribution, the method for calculating information quality (IQ) was proposed based on a multidimensional model resulting from uncertainty modeling. This model incorporated both the states of information and the features and dimensions of quality, allowing for a thorough description of the full ICT system [2]. As a result, the provided method enabled the determination of multilayer dependencies in complex IQ models of ICT systems composed of the states of information, IQ dimensions, and features of these dimensions, both dependently and independently (serial and parallel). This approach makes it possible to reduce the level of intelligence of an ICT system to a single indicator that can be used to evaluate the system. The article also provided a simulation and an illustration of how IQ aspects affect the IQ of an ICT system. The example employed mathematical proof as a method to evaluate the uncertainty of independent elements, and it was extended by computations of dependent elements. The simulation resulted in an approximated correlation, which was presented as expected.

3. The Impact of the Temperature of the Tripping Thresholds of System Detection Circuits for Intrusion Detection

The contribution to this theme [3] is one of the few publications that sought to practically verify the level of security and stability offered by electronic security systems under variable climatic conditions. The authors performed a literature review through which they revealed that the influence of temperature on the tripping thresholds of SSWiN supervisory lines has not been addressed thus far. In this publication, the electrical signals and resistance values defining the individual states of the system (such as alarm, no alarm, tampering) were determined, among others, through the use of parametric resistors and were considered a diagnostic issue This results in information about the security state of the system, the reliability of which may be affected by climatic conditions in the operating environment of electronic security systems. Thus, it represents a separate aspect related to the reliability of electronic security systems. The second contribution concerns the reliability of the hardware layer [4]. The conclusions formulated in the final part of this study can serve as a reference for specialists and experts analyzing the causes of false alarms in intruder alarm systems, and more specifically, in the case of system analyses carried out by manufacturers, which allow us to exclude the temperature of the operating environment of both the main board of the SSWiN and the parametric resistors themselves as a factor causing false alarms. Based on practical operational measurements performed in a climatic chamber, the authors of this paper proposed mathematical formulas to determine the optimum range of values of parametric resistors that guarantee the correct distinguishability of states of supervisory lines by the SSWiN, taking into account the temperature range of $-25.1 \div +60.0$ °C and the resistivity of the wires that form them.

Scientific considerations were focused on the attempt to verify the influence of the temperature of the environment of burglary and robbery signaling systems on the thresholds of tripping its supervisory lines. Assuming that the variation in the temperature of the environment of the main board of the burglary and robbery system (considered as a whole) can significantly affect the electrical parameters of its supervisory line to such an extent, the research aimed to verify the hypothesis that it is possible to change the interpretation of the observed state in the aforementioned part of the circuit from the state "no violation of the line" to the "violation of the line". This would prove that the climatic conditions (more precisely, the temperature of the work environment) of such a system should be taken into account as a factor influencing the states of supervisory lines and thus causing false alarms [5].

Based on the presented test results, the authors stated that the tested systems could, without major damage to the reliability of the security states signaled via supervisory lines, operate under climatic conditions exceeding the temperature range declared by the manufacturer (and in the case of the lower limit exceeding to a large extent). It was also found that, based on the performed tests in the case of a particular SSWiN system, the environmental conditions of the control panel itself as well as of the parametric resistors could be completely excluded as the source of false alarms. The authors revealed that the specific values of parametric resistors recommended by the manufacturer of the tested SSWiN were not the only ones that can be used. Based on the proposed relationships, which considered the resistivity of the wires forming the supervisory lines, the authors were able to determine the range of values of parametric resistors that can be used in an SSWiN system without affecting the reliability of the states generated by the supervisory lines in a wide, practically achievable temperature range of the SSWiN operating environment. The resistivity of the wires, which is another influential factor, in supervisory lines was also taken into account.

4. Operational Analysis of Fire Alarm Systems with a Focused, Dispersed, and Mixed Structure in Critical Infrastructure Buildings

In [6], the authors concocted creative ways to show how a few fire alarm systems (FAS) work. Two basic indicators of FAS exploitation were determined, i.e., damage intensity and renewal intensity μ. In this study, the exploitation indicators were determined for 10 different FAS systems, which were used in different external and internal environments. The components, modules, damage and alarm signal transmission systems, and the equipment of these systems are used in critical infrastructure buildings [7]. They are under the direct influence of the Earth's changing external environment, in particular, temperature change, precipitation, pressure, and humidity. The authors of this contribution analyzed the process of the operation of FAS using the data collected in event logs and recorded on an ongoing basis in the non-volatile memory of the fire alarm control panel (CSP). All the FAS systems were operated within the boundaries of one country. An assumption was made in the article about the FAS operating process, namely that the systems operated under similar environmental conditions. More than 80,000 event records for various manufacturers of these systems were included in the analysis of the exploitation process and the determination of intensity indicators—damage and renewal μ. The authors of the article used Markov chains to estimate selected indicators of the FAS operating processes, such as the reliability of operation R(t) and probabilities of transitions from different technical states (e.g., a fit state to safety or unfit states). This enabled the determination of the basic reliability and safety indicators of the FAS operating process. To determine these indicators, the authors used a computer application, namely ReliaSoft's BlockSim computer program. The determined operational indicators provide additional value for the comparison of FAS exploitation processes with different reliability structures.

5. The Issue of Operating Security Systems in Terms of the Impact of Electromagnetic Interference Unintentionally Generated

The first contribution to this theme [8] discussed what occurs in an electronic security system, in this case, a CCTV system, when medium-voltage lines accidentally produce electromagnetic fields in the low-frequency band.

It is possible to account for the effects of these disturbances on the severity of damage to the components, devices, and the entire security system by performing accurate measurements of the electromagnetic field's constituents, induction B of the magnetic field, and intensity E of the electric field for the chosen frequency range. This is a novel method for analyzing the impact of electromagnetic fields from the low-frequency range on the severity of damage to the elements, and as a result, the article benefitted from the authors' extensive experience in railroads when the use of electronic security systems was discussed in areas where the Earth's natural magnetic and electrical environment has been "contaminated". The fact that the CCTV system was housed in a metal container led the authors of the next contribution to conduct a study on shielding the electromagnetic field for the magnetic and electrical components [9]. They assessed the effectiveness of the shielding and how it affected the severity of damage to the security system's equipment and components. This is a new way to examine and determine how the electromagnetic field in the low-frequency region affects the safety and dependability of certain electronic systems and devices.

The operational indicators of the chosen security system were significantly impacted by the conducted study of the electromagnetic environment and the analysis of the operating process of the chosen security system in terms of the impact of electromagnetic interference unintentionally produced during the entire process of using this system. By making a model for system operation, the exact mathematical relationships for how electromagnetic fields affect the process can be found. This has a considerable effect on the likelihood of the system undergoing different states.

6. Analysis and Assessment of Railway CCTV System Operating Reliability

The authors of [10] discussed the CCTV system at PKP Polskie Linie Kolejowe S.A., together with the network and server infrastructure, which is novel. Following the guidelines of the national railroad infrastructure management, an operational model of the centralized CCTV system was created, assuming states of partial efficiency. The operational model was used by the authors to study, analyze, and rate the operational dependability of railroad CCTV systems in terms of the operational model's assumptions made by the national railroad infrastructure management. An integrated system structure was presented in this contribution. The odds of the system experiencing the assumed states were computed using the model as the foundation. Calculations were carried out, which revealed the centralized CCTV system's excellent reliability and compliance with the expectations of PKP Polskie Linie Kolejowe S.A. in this area. The 99.88 percent chance of the evaluated video surveillance system's remaining fully operational within a year demonstrates the high level of security of the solutions used in such a large system. The system under study is one of the largest of its kind made in the European Union and in Poland. This makes it an important step toward making and using similar video monitoring systems in the future [11].

The centralized CCTV (video surveillance) system complies with all the standards set forth by the national railroad infrastructure management in the rules and documents that make up the system's framework. By using this method, it was possible to optimize the values of the dependability indicators and streamline the functioning of the system under investigation. Before raising the standards for how quickly repairs can be performed, a cost-effectiveness study needs to be conducted because fast repairs can lead to much higher costs.

7. Assessment of the Reliability of Wind Farm Devices in the Operation Process

In the first contribution to this theme, the authors focused on the problem of simulations testing the quality of the operating process. To this end, they discussed the regeneration of operating characteristics that increase the reliability of wind farm (WF) equipment [12]. In the article, much of the discussion revolved around the determination of the extent of the reliability of WF devices based on the average time between failures, which is one of the factors that can change their degree of reliability.

The application of this research parameter to the reliability of WF in this way has not yet been undertaken in the literature. The novelty of this article is also in its use as a research tool in the form of the LabView computer program. The obtained results from the simulation tests provided interesting insights and were not presented in previous studies in the form considered in this article. Thus, the task of understanding the reliability of wind farm equipment was the main research goal of the authors.

The basis for the reliability of the results of any simulation study is the developed study plan, the input data, and the quality of the developed models of the given process. The first problem is fundamental. Reliable input data can be determined only based on the study of appropriate time quantities occurring in the real-time study of the exploitation process of wind farm equipment. In the simulation study, the time data from the study of the technical documentation related to the exploitation process of the equipment of one wind farm located in the north of Poland were gathered. Then, the theoretical models of the exploitation process of wind farm equipment presented in the literature were discussed, which were based on the Kolmogorov–Chapman equations. The models were properly and correctly developed. A valuable software application, LabView, was used for simulation studies. Thus, it can be assumed that the results of the simulation studies are valid and reliable [13].

The problem of testing the reliability properties of wind farm equipment during its operation, as presented in this article, is a difficult organizational and technical task. The difficulty of this result is also due to the acquisition of input data for the research. The numerical data describing the operating process of the wind farm equipment were obtained through research carried out over a long period. It was assumed that the duration of observation (measurement of downtime, useful life, etc.) would be sufficient for one year. On the other hand, the reliability tests of wind farm devices were planned to be carried out as a simulation test in a further study. This type of research requires the knowledge and description of the actual operating process of the wind farm equipment and the determination of reliable input data for the research. A well-designed research plan for wind farm equipment, as well as well-developed testing methods, is at the heart of each study. The basis for the simulation studies of the operating process of wind farm equipment is a developed model of the organization of the operating process. Hence, a model of the operating process of wind farm equipment was developed, which is termed the four-stage model in the literature.

8. Conclusions

The articles amassed in this Special Issue include crucial topics related to the modeling of the exploitation of technological objects and the research, assessment, and reliability analysis of the exploitation of objects by intelligent systems. The overarching theme of this Special Issue is intelligent systems that support energy devices and other complex technological objects, as well as the modeling, testing, and analysis of their reliability in the operating process. In each article, a primary research question was introduced, followed by a synopsis of the findings. The modeling, testing, assessment, and analysis of the dependability of technical objects' operating processes through the use of intelligent systems are just a few of the topics covered in depth in this collection.

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References

1. Stawowy, M.; Duer, S.; Paś, J.; Wawrzyński, W. Determining information quality in ICT systems. *Energies* **2021**, *14*, 5549. [CrossRef]
2. Stawowy, M. *Method of Multilayer Modeling of Uncertainty in Estimating the Information Quality of ICT Systems in Transport*; Publishing House Warsaw University of Technology: Warsaw, Poland, 2019.
3. Łukasiak, J.; Rosiński, A.; Wiśnios, W. The Impact of Temperature of the Tripping Thresholds of Intrusion Detection System Detection Circuits. *Energies* **2021**, *14*, 6851. [CrossRef]
4. Paś, J.; Rosiński, A.; Białek, K. A reliability-exploitation analysis of a static converter taking into account electromagnetic interference. *Transp. Telecommun.* **2021**, *22*, 217–229. [CrossRef]
5. Krzykowska-Piotrowska, K.; Dudek, E.; Siergiejczyk, M.; Rosiński, A.; Wawrzyński, W. Is Secure Communication in the R2I (Robot-to-Infrastructure) Model Possible? Identification of Threats. *Energies* **2021**, *14*, 4702. [CrossRef]
6. Jakubowski, K.; Paś, J.; Duer, S.; Bugaj, J. Operational Analysis of Fire Alarm Systems with a Focused, Dispersed and Mixed Structure in Critical Infrastructure Buildings. *Energies* **2021**, *14*, 7893. [CrossRef]
7. Krzykowski, M.; Pas, J.; Rosinski, A. Assessment of the level of reliability of power supplies of the objects of critical infrastructure. In *IOP Conference Series: Earth and Environmental Science*; IOP Publishing: Bristol, UK, 2019; Volume 219, p. 012018. [CrossRef]
8. Jakubowski, K.; Paś, J.; Rosiński, A. The Issue of Operating Security Systems in Terms of the Impact of Electromagnetic Interference Generated Unintentionally. *Energies* **2021**, *14*, 8591. [CrossRef]
9. Pas, J.; Rosinski, A.; Chrzan, M.; Bialek, K. Reliability-operational analysis of the LED lighting module including electromagnetic interference. *IEEE Trans. Electromagn. Compat.* **2020**, *62*, 2747–2758. [CrossRef]
10. Siergiejczyk, M.; Kasprzyk, Z.; Rychlicki, M.; Szmigiel, P. Analysis and Assessment of Railway CCTV System Operating Reliability. *Energies* **2022**, *15*, 1701. [CrossRef]
11. Chumuang, N.; Ketcham, M.; Yingthawornsuk, T. CCTV based surveillance system for railway station security. In Proceedings of the International Conference on Digital Arts, Media and Technology (ICDAMT), Phayao, Thailand, 25–28 February 2018; pp. 7–12. [CrossRef]
12. Duer, S.; Paś, J.; Hapka, A.; Duer, R.; Ostrowski, M.; Woźniak, M. Assessment of the Reliability of Wind Farm Devices in the Operation Process. *Energies* **2022**, *15*, 3860. [CrossRef]
13. Duer, S. Assessment of the Operation Process of Wind Power Plant's Equipment with the Use of an Artificial Neural Network. *Energies* **2020**, *13*, 2437. [CrossRef]